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(54) **Toggle Lever Tensioning Device That Can Be Actuated by Pressurizing Agent**

Toggle Lever Tensioning Device That Can Be Actuated by Pressurizing Agent

Class

The innovation pertains to a toggle lever tensioning device which can be actuated by pressurizing agent, especially for car body parts, with a housing and a cylinder for a piston which can be acted on on both sides by pressurizing agent pressure in an exchanging or alternating manner, which is coupled in a pivotable manner via a piston rod and at least one coupling bolt, at least one strap or the like with the toggle joint and via a toggle joint strap arrangement and a toggle joint bolt with a workpiece tensioning arm, which is arranged in a pivotable manner on a housing pivot axis that is fixed in the housing, but is mounted rotatably, wherein guide grooves arranged parallel to one another in the axial direction of the piston rod in the housing traversed by the piston rod are arranged for the possible indirect guiding of the piston rod and/or of the toggle joint.

State of the Art

A toggle lever tensioning device according to the preamble of patent claim 1 is previously known by DE-AS 22 22 686. In this toggle lever tensioning device, guide pulleys are guided in the guide grooves at the end of the piston rod of a toggle lever mechanism. Based on the toggle principle, a strong force is achieved, to be precise using a pneumatic cylinder, which operates in the pressure range of approx. 4 bar to 6 bar. In spite of this relatively low air pressure, a strong tensioning force is achieved by the toggle joint. The more the strap leads into the dead center, the stronger is this tensioning force. This tensioning force is theoretically infinitely strong in the dead center position. To avoid a high wear or damage to components, the strap is therefore set at approx. 8°. However, this leads to the toggle lever tensioning device not being able to operate in a self-locking manner.

Toggle lever tensioning devices, which guarantee a self-locking even in case of a drop in pressure and guarantee a constant tensioning force, are required in modern production and welding plants, especially of the automobile industry, however. This is especially required in mobile devices, e.g., pallet carts of the automobile industry, where the individual welding operations take place within a synchronized system and where the entire system is supplied only once with energy (compressed air).

Furthermore, a constant tensioning force, at least over a certain tensioning path, would be desired in itself. However, all previous toggle lever tensioning devices develop different tensioning forces. As a result, the parts to be tensioned, e.g., car body sheets of the automobile industry, experience an in itself uncertain tensioning force, such that the position of the tensioned-together parts in the device is imprecise and consequently not true to size. Thus, inaccurate fits may arise in, e.g., car body parts because of the tolerances caused by different tensioning forces, which is undesirable.

A toggle lever tensioning device was proposed by the Applicant in German Patent Application No. P 31 30 942.9, in which the strap of the toggle joint is designed as an elastic spring joint, which travels in the end tensioning position for 30 minutes over the dead center position. However, this design leads to high wear, since the spring force of the strap of the toggle joint is constant in the area of the dead center position and, furthermore, the characteristic of a spring differs sharply depending on the curing process, etc., so that constant tensioning forces, at least in the area of the end tensioning position, cannot be implemented with absolute certainty.

Object

The basic object of the present innovation is to improve a toggle lever tensioning device that can be actuated by pressurizing agent according to the preamble of patent claim 1 to the extent that within a predeterminable tensioning area, equal or practically constant tensioning forces or torques can be achieved on the workpiece tensioning arm.

Accomplishment

The object is accomplished by the features provided in claim 1.

Some Advantages

In the toggle lever tensioning device that can be actuated by pressurizing agent according to the present innovation, the guide grooves arranged in the housing have a curved design at least in the tensioning area according to only one radius, respectively. Consequently, it is achieved that within a predeterminable area, the tensioning force can be maintained equal or almost equal. This area may begin already before the otherwise usual dead center position and may be maintained over the otherwise usual dead center position, such that a dead center position is no longer given in a toggle lever tensioning device according to the present innovation. For example, this constant tensioning force may be reached shortly before placing the workpiece tensioning arm on metal sheets to be connected to one another and be maintained over a certain path area, which is moved further [sic – Tr.Ed.] the workpiece tensioning arm bolt during the tensioning with the toggle joint. This area, in which the constant or almost constant tensioning force can be achieved in a toggle lever tensioning device according to the present innovation, can be achieved, for example, over a range of 2 mm to 10 mm, preferably from approx. 4 mm to 5 mm, in relation to the workpiece tensioning arm end. In this way, the drawbacks described in connection with the state of the art are avoided.

As an alternative, the opposing guide walls of the guide grooves may be defined instead of only by a radius each, rather also by a set of curves, which are formed, for example, by radii, which blend into one another with as few discontinuities as possible – claim 2.

Other Embodiments of the Invention

An especially advantageous embodiment is described in claim 3.

Other embodiments of the invention arise from claims 4 through 17.

In the embodiments according to claims 10 through 17, one or more blocking devices, which prevent an unintentional detachment of the workpiece tensioning arm in case of a drop in pressure, are assigned to the toggle lever tensioning device. This is advantageous if, for example, there is a drop in the pressurizing agent pressure, especially of the compressed air, or else if the toggle lever tensioning devices have to remain in the tensioned position over the weekend or during a shift change.

The present innovation is illustrated – partly schematically – for example in the drawing, in which:

Figure 1 shows a toggle lever tensioning device, partly in longitudinal section and partly in a lateral view, with workpiece tensioning arm resting on two flat sheet sections lying on one another in the tensioned position;

Figure 2 shows the toggle lever tensioning device shown in Figure 1, but with the workpiece tensioning arm opened, without sheets;

Figure 3 shows a section along line III-III of Figure 1;

Figure 4 shows a circuit diagram equivalent to Figure 1, on a larger scale;

Figure 5 shows a force-path-tension curve in an embodiment according to the present innovation, and

Figure 6 shows a section along line VI-VI of Figure 1.

In the drawing, the present innovation is illustrated using a toggle lever tensioning device actuated by compressed air, which [device] can especially advantageously be used in car body production in the automobile industry.

A single- or multicomponent housing is designated by reference number 1, which has on one side a cylinder 2 with a piston guided therein in an axially longitudinally displaceable manner and in a sealing manner.

Reference numbers 4 and 5 designate connecting ducts, to which pressurizing agents lines (not shown) are connected, through which alternatingly the piston 3 can be acted on with pressurizing agent pressure in a controlled manner.

To the piston 3 is connected a piston rod 6, which is guided in a housing part 7 facing the piston 3 in a longitudinally displaceable and sealing manner and passes through an open movement space 8, with whose walls the piston rod 6 itself has no contact.

To guide the toggle joint and thus also the piston rod 6, guide grooves 9 and 10, each defined by end sides, running parallel to one another on sides diametrically opposed to one another, which have the same size and same shape and run parallel to one another, i.e., in the same height range, are provided (Figure 3).

Each of the guide grooves 9, 10 has a U-shaped design in the cross section shown in Figure 3, i.e., is at least defined by guide walls 11, 12 and 13, 14 and respectively by a closing wall running at right angles thereto, which is not designated in greater detail.

The piston rod 6 is provided at its end with a threaded section, which is screwed into a blind hole, likewise provided with a threaded section, of a coupling piece 16, which in the lateral view has an approximately T shape (not shown). The T-shaped coupling piece 16 extends with a web between two plate-shaped straps 17, 18 spaced apart and running parallel to one another, which form a joint strap arrangement 22. The two straps 17, 18 of the joint strap arrangement 22 as well as the web of the coupling piece 16 have bores, which are aligned with one another, through which the coupling bolt 15 passes, so that the piston rod 6 is also pivotably connected to the joint strap arrangement 22 via the coupling piece 16. The coupling bolt 15 has, at its end areas, a guide pulley 20 and 21 each (Figure 3), which is guided in an unwindable manner in the guide grooves 9 and 10, and to be precise at the guide walls 11, 12 and 13, 14. During the pivoting of the toggle joint arrangement, the web of the coupling piece 16 thus remains between the two straps 17 and 18.

A joint strap arrangement 22 of the toggle joint is connected to the central longitudinal section of the coupling bolt 15 in such a way that it is vertically pivotable by a defined extent in the drawing plane shown in Figure 1. At the other end, the joint strap arrangement 22 is connected to a toggle joint bolt 23 (Figures 1 and 2), which runs with its longitudinal axis parallel to the coupling bolt 15. The toggle joint bolt 23 is, in principle, designed as the coupling bolt 15 and likewise has at each end area at least one guide pulley 24, 25 each (Figure 3), which, just like the guide pulleys 20, 21, are guided in the guide grooves 9 and 10, and to be precise unwinding at the guide walls 11, 12 and 13, 14.

A toggle joint strap arrangement 26, which is pivotable in the same plane just like the joint strap arrangement 22, is pivotably connected to the central longitudinal section of the toggle joint bolt 23. At its end facing away from the toggle joint bolt 23, the toggle joint strap arrangement 26 is provided with a bore, through which passes a workpiece tensioning arm pivot bolt 27, via which a workpiece tensioning arm 28 is pivotably coupled, which is pivotable about a housing pivot axis 29 mounted stationarily in the housing 1 depending on the pressurizing agent action of the piston 3 either through the duct 5 or the duct 4 in direction X or Y, respectively.

Figure 1 shows the tensioned position, in which the workpiece tensioning arm 28 is placed onto sheets 30, which lie on a projection of the housing 1 or on a matrix (not shown).

In the longitudinal direction, guide grooves 9 and 10 are essentially composed of two longitudinal sections, which are, in principle, designated by A and B in Figures 1 and 2,

respectively. On the section B, the guide grooves run with their longitudinal axes parallel to the longitudinal axis of the piston rod 6, i.e., in a straight line, while the guide grooves 9, 10 on the longitudinal section A run in a curved manner according to radii in the way still to be described. In this case, the arrangement is obtained such that the pair of guide pulleys 20, 21 assigned to the coupling bolt 15 adjacent to the cylinder 2 is always guided only in straight-line section B of the guide grooves 9 and 10, while the front pair of guide pulleys 24 and 25 assigned to the toggle joint may enter the opened position (Figure 2) at least in the transition area, but preferably in the straight section of the guide grooves 9 and 10 as well, while these guide pulleys 24 and 25 of the toggle joint are guided at least in a predetermined area still to be described through section A, i.e., through the guide grooves 9 and 10 running in a curved manner.

These guide pulleys 24 and 25 of the toggle joint and the pivot center, i.e., imaginary longitudinal axis of the toggle joint bolt 23 are shown only schematically in Figure 4. A partial section of the guide grooves running in a straight line with longitudinal section B and the longitudinal section A running upwards in a curved manner in the drawing plane is clearly seen from Figure 4. The center 31 of the workpiece pivot arm bolt [sic – Tr.Ed.] 27 moves from a bottom position in the drawing plane (Figure 4) into an upper position in the drawing plane (Figure 4). This circular arc, which covered the center 31 in Figure 4, corresponds to the example shown in Figure 1 of the tensioning position of -4 to 2, i.e., a tensioning range, in which practically the same tensioning force can be obtained, or in other words, the curve section in Figure 5, in which the curve runs in a straight line between maximum set point and nominal value, i.e., shows an equal tensioning force. The center 31 moves herewith on a circular arc, and the pivot center coincides with the longitudinal axis of the housing pivot axis 29. The angle, which covers the center 31 hereby on its tensioning path in Figure 1 designated by -4 to 2, is designated by α in Figure 4 and is an acute angle.

If the center 31 is connected to the center of the housing pivot axis 29, then a line 32 is obtained. On this line 32 lies a point 33, from which the radii 34 and 35 are drawn to define the guide walls 11, 13 and 12, 14 of the section A, running in a curved manner, of the guide grooves 9, 10 by only one radius each. The radius of the central line of the guide grooves is designated by 36. A straight line, which connects the center 31 and the pivot center of the toggle joint bolt 23 and runs at right angles or almost at right angles to the line 32, is designated by the reference number 37. A circular section, on which the pivot center of the toggle joint bolt 23 moves, is designated by 44. The line 37 and the central line radius 36 form an acute angle β. The center 33 lies relatively close to the center, to be precise approx. 20% of the overall length of the line 32, which, of course, depends on the dimensions.

As is seen, the guide walls 11, 12, 13 and 14 consequently curved in one direction, i.e., upwards in the drawing plane of Figure 4, blend without discontinuities over a circular arc each smoothly into the straight-line section B of the guide grooves 9 and 10. However, the guide pulleys 20, 21 of the toggle joint arrangement reach the curved area A in case of no pivot position, because jams might otherwise occur. Rather, only the guide pulleys 24, 25 of the toggle joint arrangement are guided in the guide groove section A, which is curved by only one radius each,

i.e., running in a circular arc pattern, and the arrangement, especially the position of the point 33 is selected, such that an as constant tensioning force as possible is obtained in a predetermined area over and above the dead center position present in common devices of this type. This is especially obvious from Figure 5, in which the tensioning force is shown as a function of the path that the workpiece tensioning arm 28 covers. Numbers -4, -3, -2, -1, 0, as well as 1 and 2 are drawn in Figure 1. This means that at position -4, i.e., before placing tensioning arm 28 on sheets 30, the full force is already achieved and this is maintained up to +2. This is clearly seen in Figure 5. This tensioning force is constant or almost constant in a very wide range. Consequently, excess stresses do not occur, which are otherwise to be feared in case of pure dead center locking of usual toggle lever tensioning devices. Theoretically, as is well known, when reaching the dead center, forces occur, which are infinitely high, which means that damage or high wear may occur. The arrangement is made such that, in a predetermined tolerance field, which is described by "maximum set point" and "nominal value" in Figure 5, the tensioning force is maintained constant before the placing of the tensioning arm 28 and beyond or almost constant for practical needs.

The path curves at A can be produced in an especially simple manner, e.g., on CNC-controlled machines, because they are radii, since, for example, the guide walls 11 and 13, 12 and 14 are each defined only a single radius according to Figure 4.

It is also possible to create the section A, running in a curved pattern, of the guide grooves 9 and 10 by a set of curves, which are designed, as it were, infinitesimally small, and, however, care must be taken that there are no jerky stresses, movements or the like of the workpiece tensioning arm 28. In the embodiment shown, the angle β is approx. 10°, but may also be larger or smaller.

Blocking devices, which in the present case comprise small pistons, which are to be acted on at least on one side by pressurizing agent pressure and press against the outer jacket surface of the piston rod 6 with suitable brake shoes in order to brake same, so that an intentional detachment of the workpiece tensioning arm 28 cannot occur in case of pressurizing agent failure or pressure fluctuations, are designated by the reference numbers 38 and 39. This is especially advantageous for car body construction, e.g., when sheets 30 have to be kept tensioned over the weekend under pressurizing agent pressure. The lifting of the blocking devices can occur by springs, or else by opposed pressurizing agent action of the pistons of the blocking devices arranged in cylinders. The pressurizing agent is fed via ducts arranged in the cylinder wall (not shown).

In the embodiment shown in Figures 1 and 2, blocking devices 40, 41 in the form of tensioning pistons are also assigned to piston 3, which are guided in cylinders in a pressurizing agent sealed manner. The blocking devices 40, 41 work with brake shoes against the inner cylinder jacket surface 42 and consequently brake the device as needed. The pressurizing agent may be fed via a bore (not shown), which penetrates the piston rod and the bottom, or else through a tube, which protrudes from the cylinder bottom 42 centrally into the piston and is guided in a sealed manner, to be able to feed pressurizing agent here into the blocking device through slots in the area of the tensioning position. The blocking devices 40, 41 can be lifted by springs (not shown), which are

further prestressed during the tensioning. These blocking devices 40 and 41 represent a further, additional securing against unintentional detachment of the workpiece tensioning arm 28. Of course, it is not necessary in all cases to provide all blocking devices 38, 39 and 41, 40. In some cases, it is sufficient to assign blocking devices only to the piston rod 6, or else to assign the blocking device 40 and 41 only to the piston 3 and to dispense with the blocking devices 38 and 39, instead.

Furthermore, it is conceivable to provide only one blocking device each at the piston rod 6 and at the piston 3, instead of two blocking devices, or to provide more than two, e.g., three or more such blocking devices, which are preferably arranged distributed at a uniform distance over the circumference.

Instead of pistons, tensioning cones, barrels or balls, which can be suitably brought into clamping contact with blocks, might be used as a blocking device.

The blocking devices may be integrated in a remote control.

The features described in the claims and in the specification as well as evident from the drawings may be essential for implementing the present innovation both alone and in any combination.

List of Reference Numbers

1	Housing
2	Cylinder
3	Piston
4	Duct, connecting duct
5	Duct, connecting duct
6	Piston rod
7	Housing part
8	Movement space
9	Guide groove
10	Guide groove
11	Guide wall
12	Guide wall
13	Guide wall
14	Guide wall
15	Coupling bolt
16	Fork-type joint
17	Strap of the joint strap arrangement 22
16	Strap of the joint strap arrangement 22
19	-
20	Guide pulley
21	Guide pulley
22	Joint strap arrangement
23	Toggle joint bolt
24	Guide pulley
25	Guide pulley
26	Toggle joint strap arrangement
27	Workpiece tensioning arm pivot bolt
28	Workpiece tensioning arm
29	Housing pivot axis
30	Sheets
31	Center, pivot center
32	Line
33	Point, center
34	Radius
35	Radius
36	Radius
37	Line
38	Blocking device
39	Blocking device
40	Blocking device
41	Blocking device

42	Cylinder jacket surface
43	Cylinder bottom
44	Circular section
A	Section of the guide grooves 9, 10 running in a curved manner
B	Guide section of the guide grooves 9, 10 running in a straight line
X	Direction of pivoting of the workpiece tensioning arm 28
Y	Direction of pivoting of the workpiece tensioning arm 28
α	Angle
β	Angle

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Claims

1. Toggle lever tensioning device that can be actuated by pressurizing agent, especially for car body parts, with a housing (1) and a cylinder (2) for a piston (3) that can be acted on on both sides by pressurizing agent pressure in an exchanging or alternating manner, which is coupled in a pivotable manner via a piston rod (6) and at least one coupling bolt (15), at least one strap or the like with the toggle joint and via a toggle joint strap arrangement (26) and a toggle joint bolt (23) with a workpiece tensioning arm (28), which is arranged in a pivotable manner on a housing pivot axis (29) that is fixed in the housing, but is rotatably mounted, wherein guide grooves (9, 10) arranged parallel to one another in the axial direction of the piston rod (6) in the housing (1) traversed by the piston rod (6) are arranged for the possible indirect guiding of the piston rod (6) and/or of the toggle joint (22, 23, 26, 27), **characterized in that** the opposing guide walls (11, 12, and 13, 14) of the guide grooves (9, 10) are arranged for the toggle joint (22, 23, 26, 27) in a curved manner towards one side of the piston rod longitudinal axis according to only one radius in such a way that an identical or almost identical remaining tensioning force on the tensioning arm (28) is obtained with the workpiece tensioning arm (28) via a predetermined pivot range of the workpiece tensioning arm (28) without reaching a dead center position.

2. Toggle lever tensioning device that can be actuated by pressurizing agent, especially for car body parts, with a housing (1) and a cylinder (2) for a piston (3) that can be acted on on both sides by pressurizing agent pressure in an exchanging or alternating manner, which is coupled in a pivotable manner via a piston rod (6) and at least one coupling bolt (15), at least one strap or the like with the toggle joint and via a toggle joint strap arrangement (26) and a toggle joint bolt (23) with a workpiece tensioning arm (28), which is arranged in a pivotable manner on a housing pivot axis (29) that is fixed in the housing, but is rotatably mounted, wherein guide grooves (9, 10) arranged parallel to one another in the axial direction of the piston rod (6) in the housing (1) traversed by the piston rod (6) are arranged for the possible indirect guiding of the piston rod (6) and/or of the toggle joint (22, 23, 26, 27), **characterized in that** the opposing guide walls (11, 12, and 13, 14) of the guide grooves (9, 10) is [sic – Tr.Ed.] each defined by a set of curves, which blend into one another with as few discontinuities as possible, on its longitudinal section (A) used for guiding the toggle joint on one side of the longitudinal axis of the piston rod (6), in such a way that an identical or almost identical remaining tensioning force on the tensioning arm

(28) is obtained with the workpiece tensioning arm (28) via a predetermined pivot range of the workpiece tensioning arm (28) without reaching a dead center position.

3. Toggle lever tensioning device in according with claim 1 or 2, **characterized in that** both the coupling bolt (15) and the toggle joint bolt (23) is [sic – Tr.Ed.] guided each via at least one pair of guide pulleys (20, 21 and 24, 25) in the guide grooves (9, 10), and in that the guide grooves (9, 10) comprise each two longitudinal sections (A and B) blending into one another without discontinuities, wherein the one section (B) runs in a straight line as well as parallel to the longitudinal axis of the piston rod (6), while the other longitudinal section (A) surrounds the section of the guide grooves (9, 10) running in a curved manner directed away from the piston rod (6), and in that the guide pulleys (20, 21) for the toggle joint bolt (15) are only guided in the section (B) running in a straight line, while guide pulleys (24, 25) of the toggle joint (22, 23, 26) are guided in the curved section (A) via a certain stroke (A), but are also guided by the guide walls (11, 12 and 13, 14) of the section (B) running in a straight line when the workpiece tensioning arm (28) is pivoted open.

4. Toggle lever tensioning device in accordance with claim 1 or one of claims following it, **characterized in that** the common center (33) of the radii (34 and 35) of the guide walls (11, 12 and 13, 14) of the curved section (A) lies on a straight, imaginary line (32) between the pivot center of the housing pivot axis (29) and the pivot center (31) of the workpiece tensioning arm pivot bolt (27), via which the toggle joint strap arrangement (26) is coupled in a pivotable manner with the toggle joint bolt (23).

5. Toggle lever tensioning device in accordance with claim 4, **characterized in that** the distance of the center (33) of the radii for the curved section (A) from the pivot center (31) of the workpiece tensioning arm pivot bolt (27) is approx. 10% to 40%, preferably 15% to 20% of the total distance between the pivot center of the housing pivot axis (29) and the pivot center (31) of the workpiece tensioning arm pivot bolt (27).

6. Toggle lever tensioning device in accordance with claim 1 or one of the claims following it, **characterized in that** a straight line placed in the tensioning position through the pivot center (31) of the workpiece tensioning arm pivot bolt (27) and connecting the center of rotation of the guide pulleys (24, 25) of the toggle joint bolt (23) and a straight line, which runs through the center of the same guide pulleys (24, 25) at the transition from the curved longitudinal section (A) into the guide section (B), running in a straight line, of the guide grooves (9, 10) and the pivot center (31), form an acute angle (β) of 10° to 40°, preferably from 15° to 20°.

7. Toggle lever tensioning device in accordance with claim 6, **characterized in that** the angle (β) is 8.5° to 12°, preferably approx. 10°.

8. Toggle lever tensioning device in accordance with claim 1 or one of the claims following it, **characterized in that** the tensioning force of the workpiece tensioning arm (28) is equal or practically equal

within an upper and a lower predetermined value in a predetermined pivot range of the workpiece tensioning arm (28).

9. Toggle lever tensioning device in accordance with claim 1 or one of the claims following it, **characterized in that** the center (31) of the workpiece tensioning arm pivot bolt (27) is displaced to a circular arc by the passing of the guide pulleys (24, 25) of the toggle joint bolt (23) from the straight-line section (B) of the guide grooves (9, 10) into the section (A) running in a curve manner up to its maximum tensioning position, and in that the pertinent sector angle is an acute angle.

10. Toggle lever tensioning device in accordance with claim 1 or one of the claims following it, **characterized in that** at least one blocking device (39 and 41) each, which blocks the toggle lever tensioning device in case of a pressure drop in the predetermined position, is assigned to the piston rod (6) and/or piston (3).

11. Toggle lever tensioning device in accordance with claim 10, **characterized in that** the blocking devices (39, 41) each comprise at least one piston, which is to be acted on on one side by pressurizing agent pressure.

12. Toggle lever tensioning device in accordance with claim 11, **characterized in that** each piston is acted on on one side by spring force.

13. Toggle lever tensioning device in accordance with claim 10 or one of the claims following it, **characterized in that** the blocking device (41) assigned to the piston (3) can be pressed against the cylinder jacket surface (42) of the cylinder (2).

14. Toggle lever tensioning device in accordance with claim 10, **characterized in that** the blocking device (39) can be pressed against the outer jacket surface of the piston rod (6).

15. Toggle lever tensioning device in accordance with claim 10 or one of the claims following it, **characterized in that** a plurality of blocking devices (38, 39 and 40, 41) are arranged over the circumference of the piston rod (6) and/or of the piston (3).

16. Toggle lever tensioning device in accordance with claim 10, **characterized in that** the blocking device comprises balls, which are arranged in a blockable manner in a cage.

17. Toggle lever tensioning device in accordance with claim 16, **characterized in that** each blocking device surrounds a plurality of barrels.

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Fig. 1

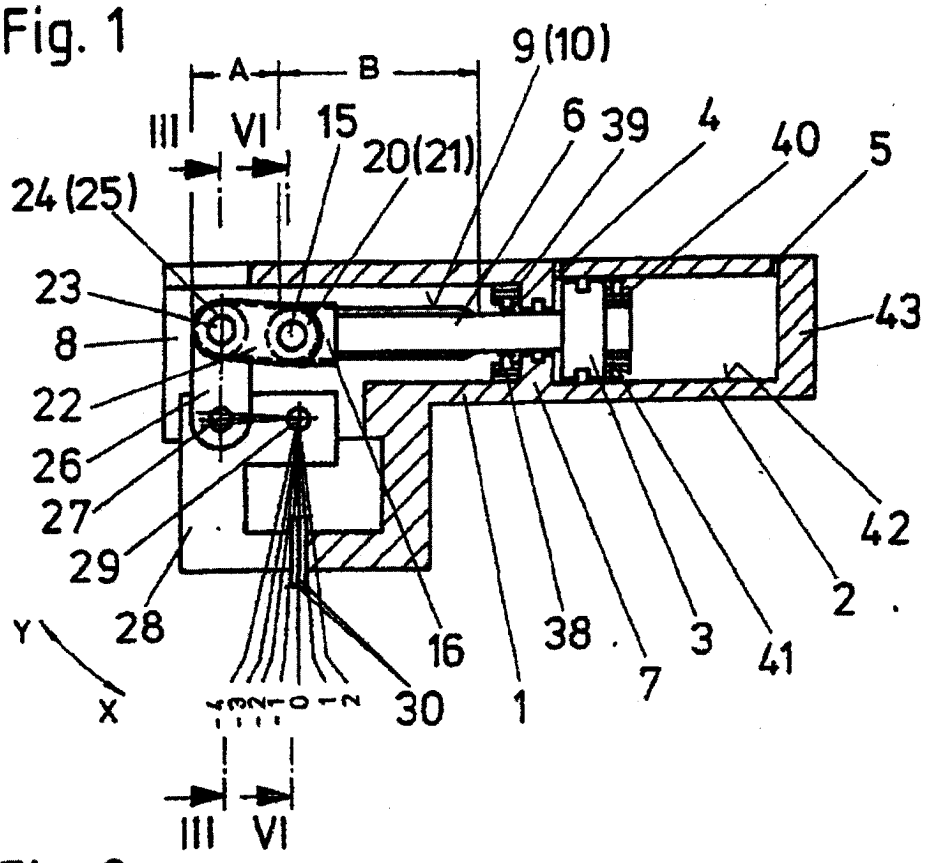

Fig. 2

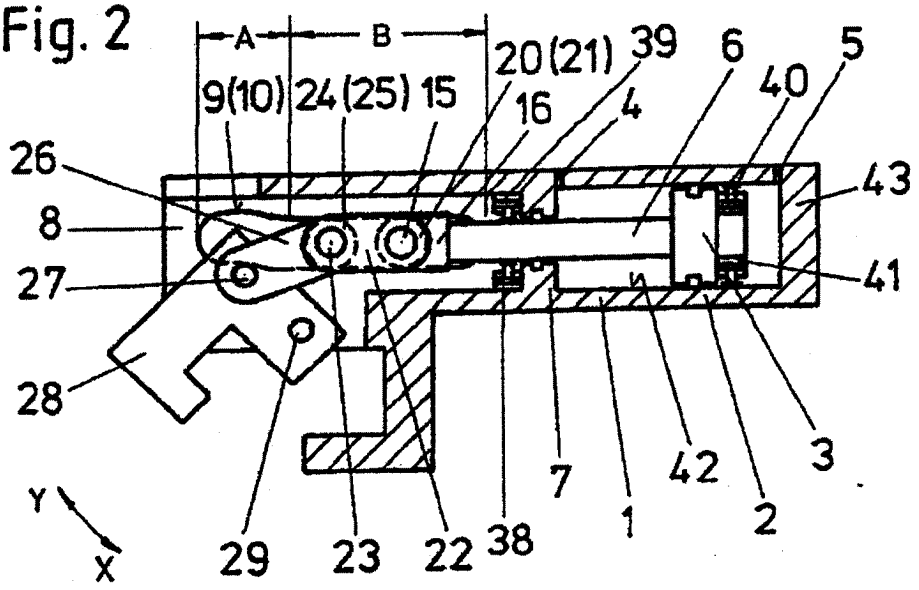

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Fig. 3

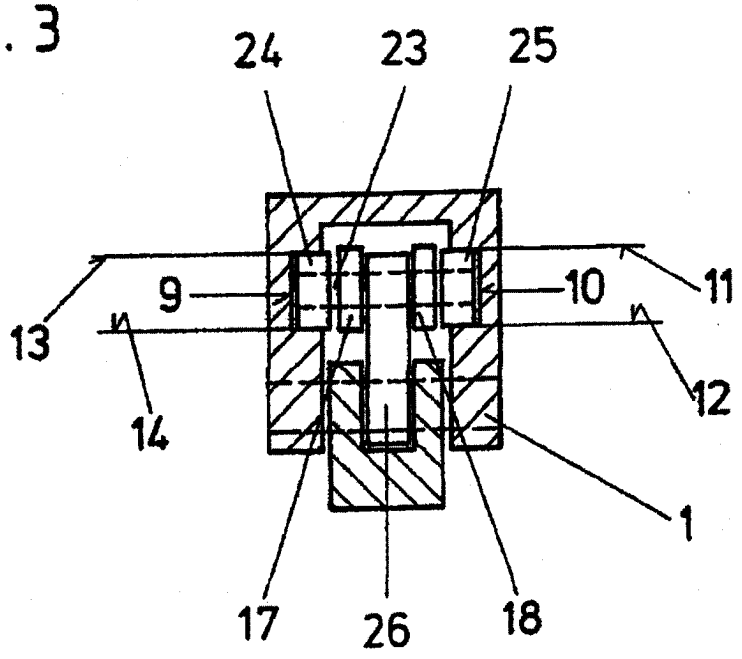

Fig. 6

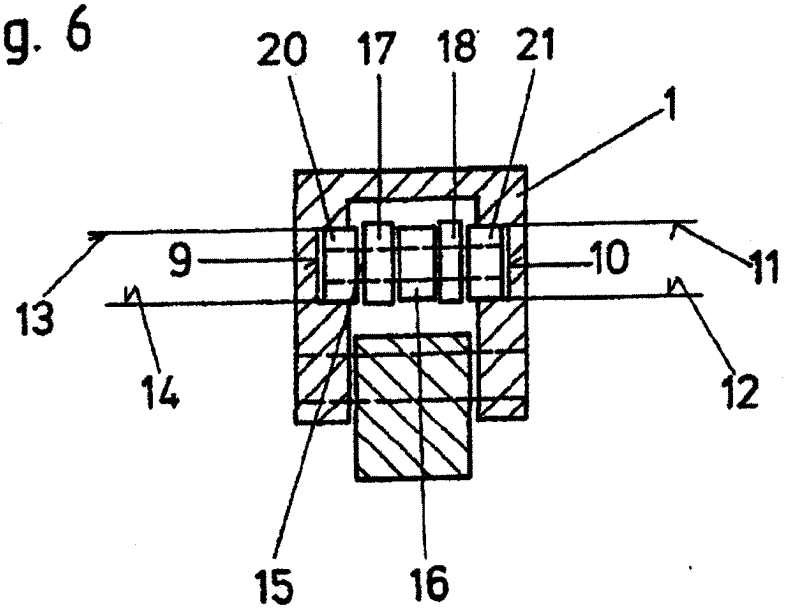

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Fig. 4

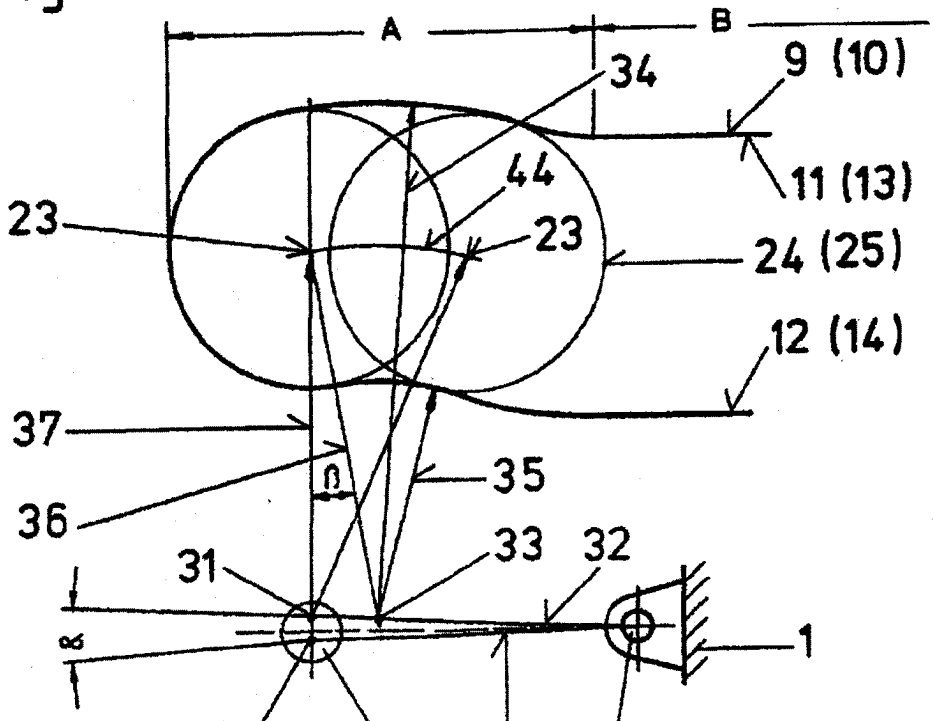
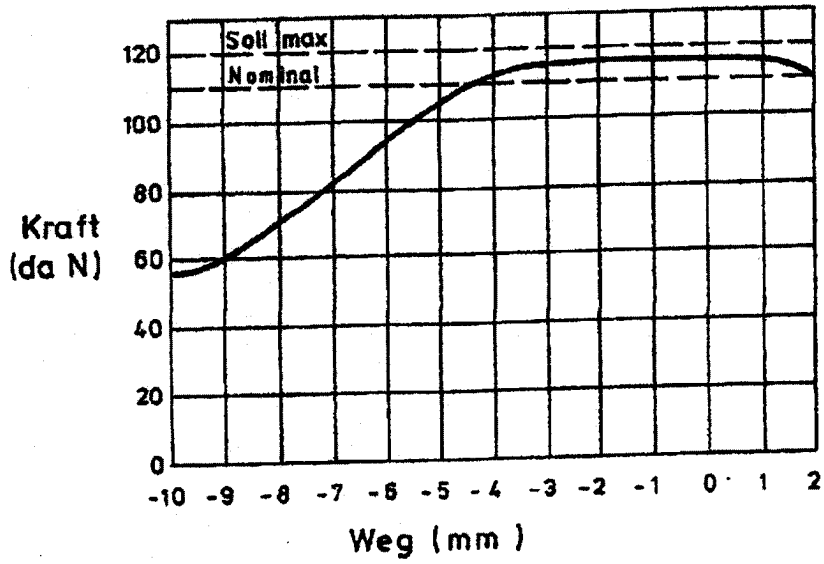


Fig. 5



KEY:
Soll max = Maximum set point
Nominal = Nominal value
Kraft = force
Weg = Path